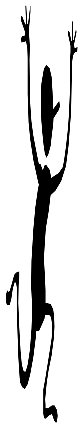
Introduction to M1 Session on VLMCs

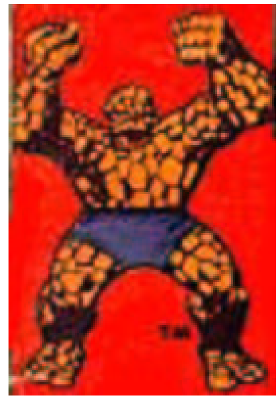
Bruce King
bking@bnl.gov

- Muon Collider Motivation & History
- Introduce Muon Collider Types & Parameters
- Neutrino Radiation May Imply Site Constraints
- Topics to Come in this Session

WHY MUON COLLIDERS?

Extend the energy frontier!





Electrons
are too light

Discovery reach
of a few TeV ?

Protons are composite
& strongly interacting

Discovery reach of
some 10's of TeV ?

$\Rightarrow$

Add Muons,
though unstable

Discovery reach of
~100 TeV (circular)?
~1 PeV (linear)???

$m_\mu \sim 206 \times m_e$

$\mu \rightarrow e\nu\nu$

$\tau_\mu = 2.2\ \mu s$

Muons have the highest potential discovery reach, using clean lepton-lepton collisions, so the successful development of muon collider technology will maximize the long-term potential of experimental HEP.

→ see following talk by Mike Berger

History of High Energy Muon Collider (HEMC) R&D

60's & 70's $\mu^+\mu^-$ colliders mentioned (Tinlot, Budker, Skrinsky, Neuffer)

1981 ionization cooling (Skrinsky & Parkhomchuk)

1994 high luminosity para. (Palmer, Neuffer); meetings & workshops

1996 "$\mu^+\mu^-$ Collider; a Feasibility Study" (83 authors) E_{CoM} = 4 TeV

1997 Muon Collider Collaboration forms, ~20-25 FTE

1998 positive recommendation from Gilman HEPAP sub-panel

1998+ co-existence with neutrino factory R&D

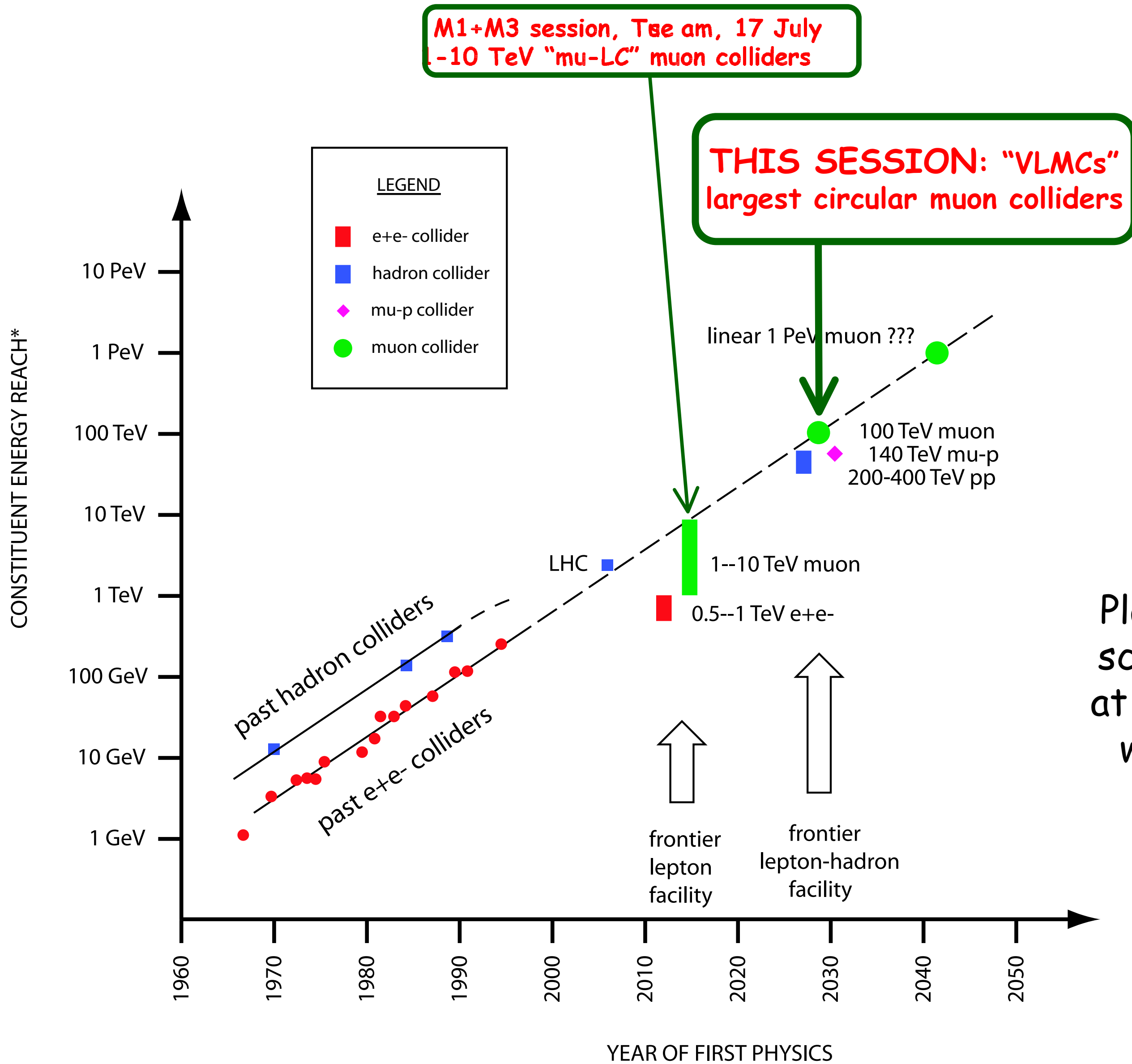
-> Neutrino Factory & Muon Collider Collaboration

1999 "status report" (108 authors) Phys. Rev. Special Topics, Accel. Beams 2, 081001 (1999)
including E_{CoM} = 100-150 GeV Higgs factory

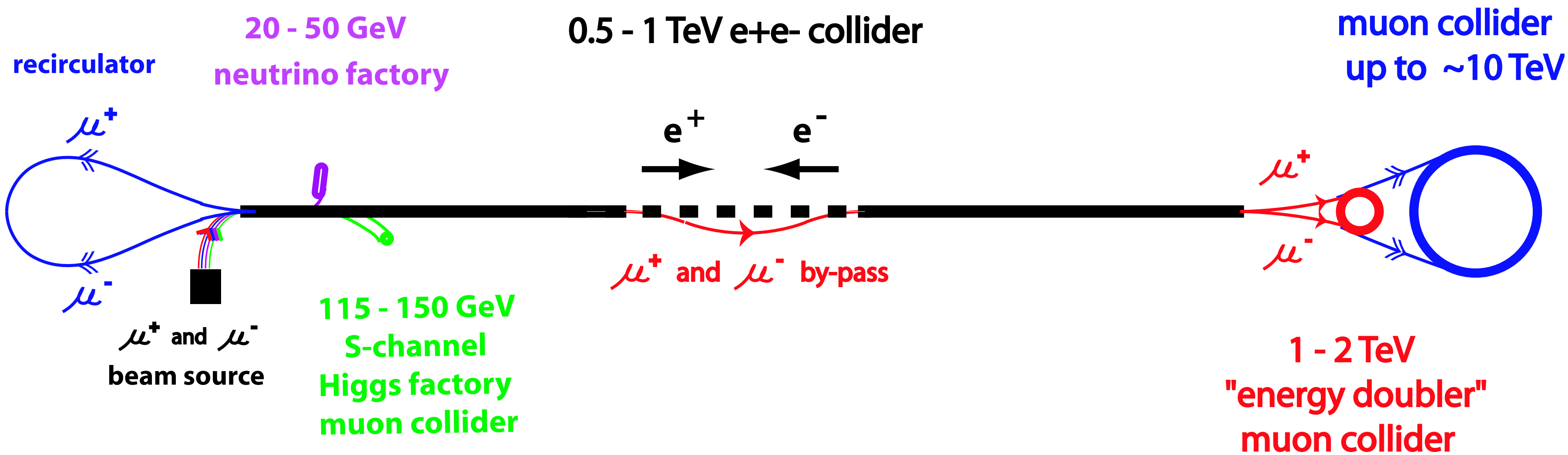
HEMC'99 workshop E_{CoM} = 10-100 TeV (was M1 session, 4 July am)

2000-01 6-Month Feasibility Study on HEMCs (CD here at Snowmass)

MUON COLLIDERS MAY BE ESSENTIAL FOR CONTINUING TO ADVANCE THE ENERGY FRONTIER AT THE HISTORICAL RATE

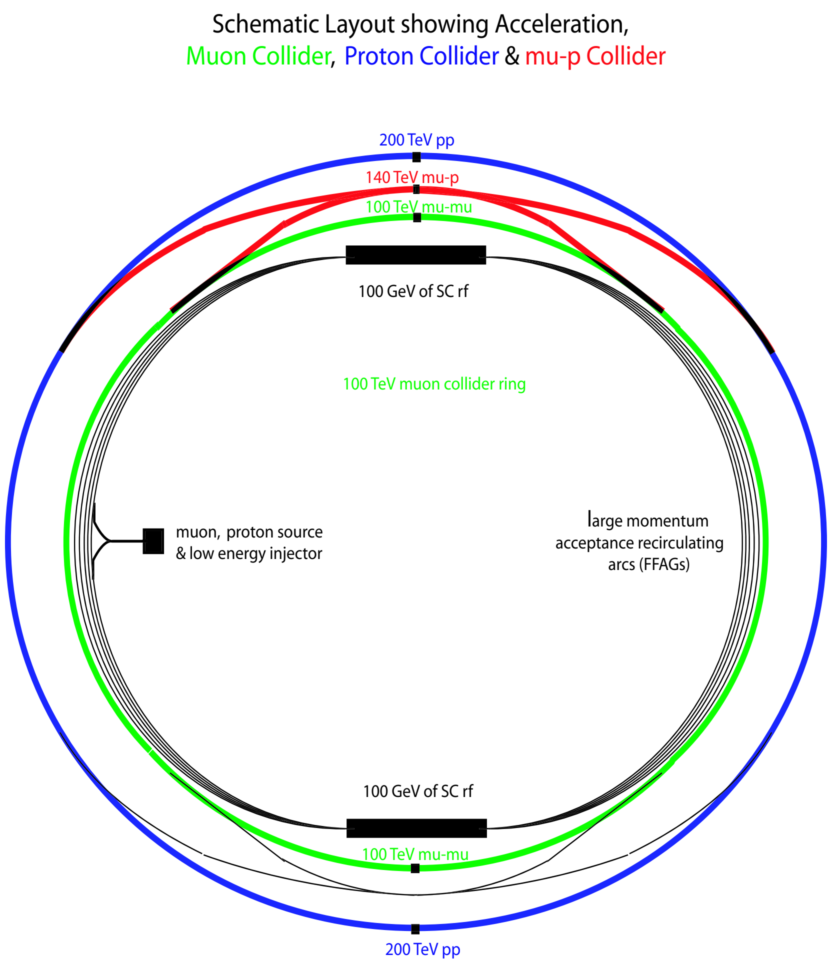


Plausible "straw-man" scenario for progress at the energy frontier with muon colliders



To be discussed in M1+M3 joint session, Tuesday am, 17 July

VLMC Scale ~ VLHC, & Could Even Share Facility



Example of VLMC + VLHC symbiosis

(BJK talk, M4 session, last Thursday)

- ✓ common magnet R&D
- ✓ same tunnel, or side-by-side
- ✓ common acceleration to ~50 TeV/beam
  - ➢ full energy for muon collider
  - ➢ ~½ energy for hadron collider
- ✓ mu-p collisions at E_{CoM} ~ 140 TeV

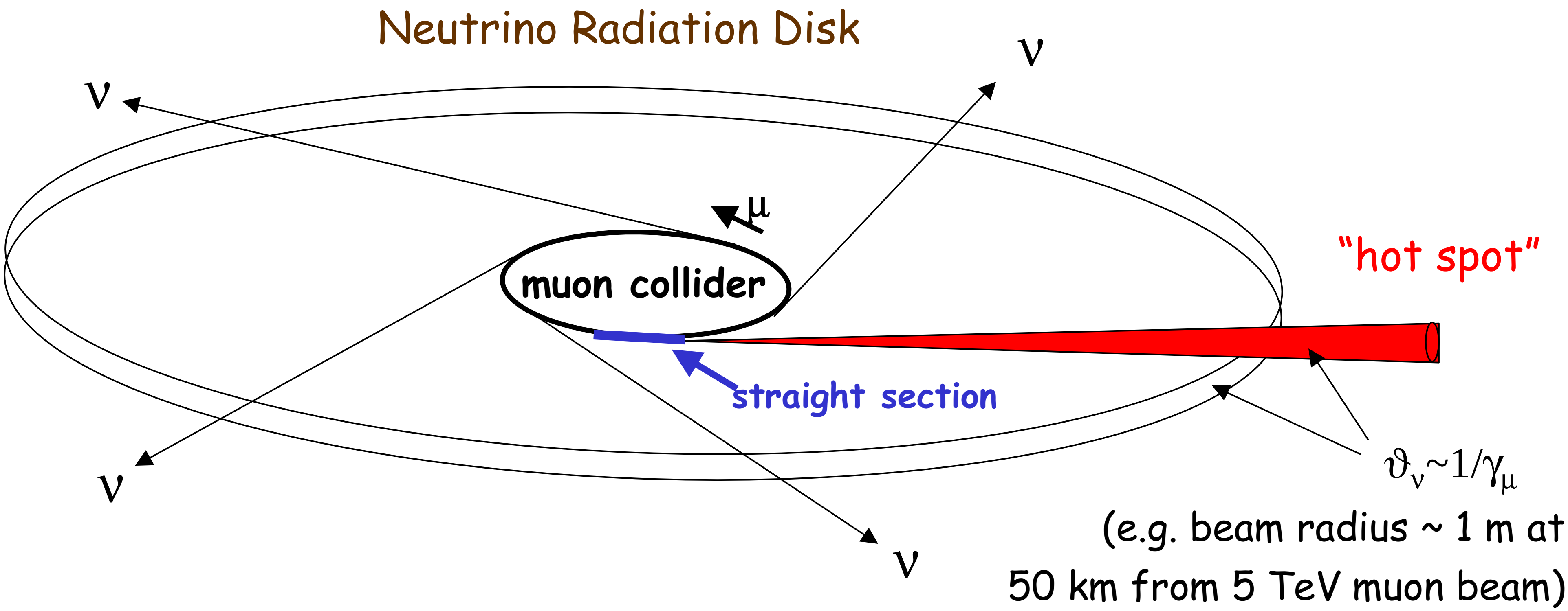
  (BJK talk, M5 session, Tuesday am, 10 July)

(SEE STRAW-MAN VLMC PARAMETER SET @ 100 TeV)

Luminosity = 2×10^{35} cm$^{-2} \cdot$s^{-1}

synch. radiation = 44 MW - defines this to be max. energy scale for circular machines

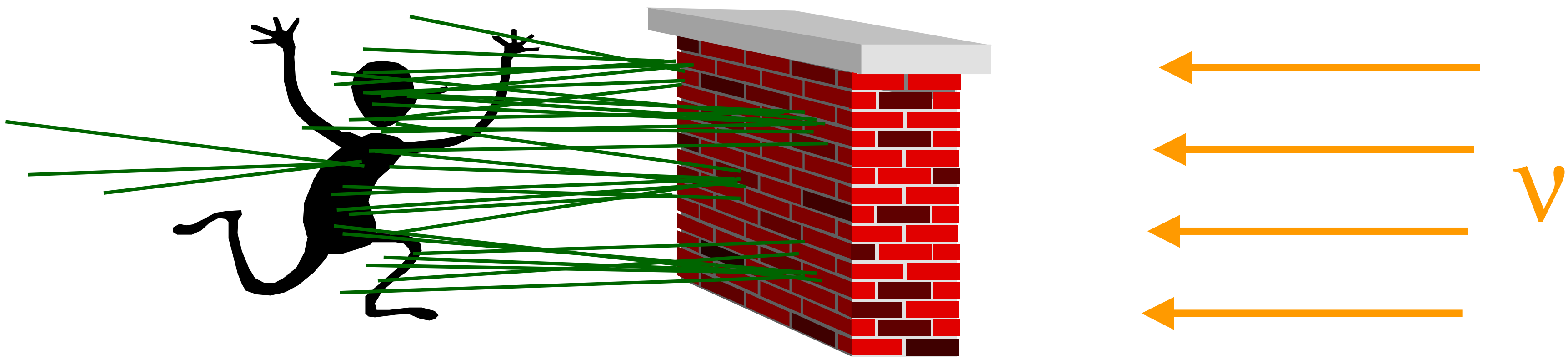
NEUTRINO RADIATION => VLMC SITE CONSTRAINTS (1 of 2)



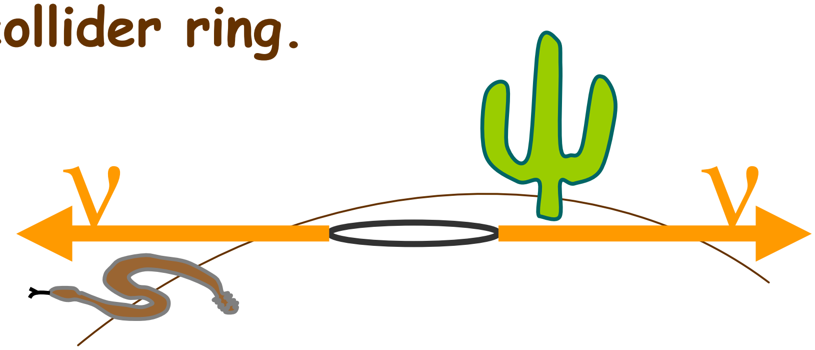
neutrino production: $\mu \to e\nu\nu$

THE OFF-SITE RADIATION CONSTRAINT

Radiation dose from charged particles from neutrino interactions in the surroundings ...



The predicted dose rises sharply with collider energy => a VLMC will need to be located at a very isolated site where no-one is in the plane of the collider ring.

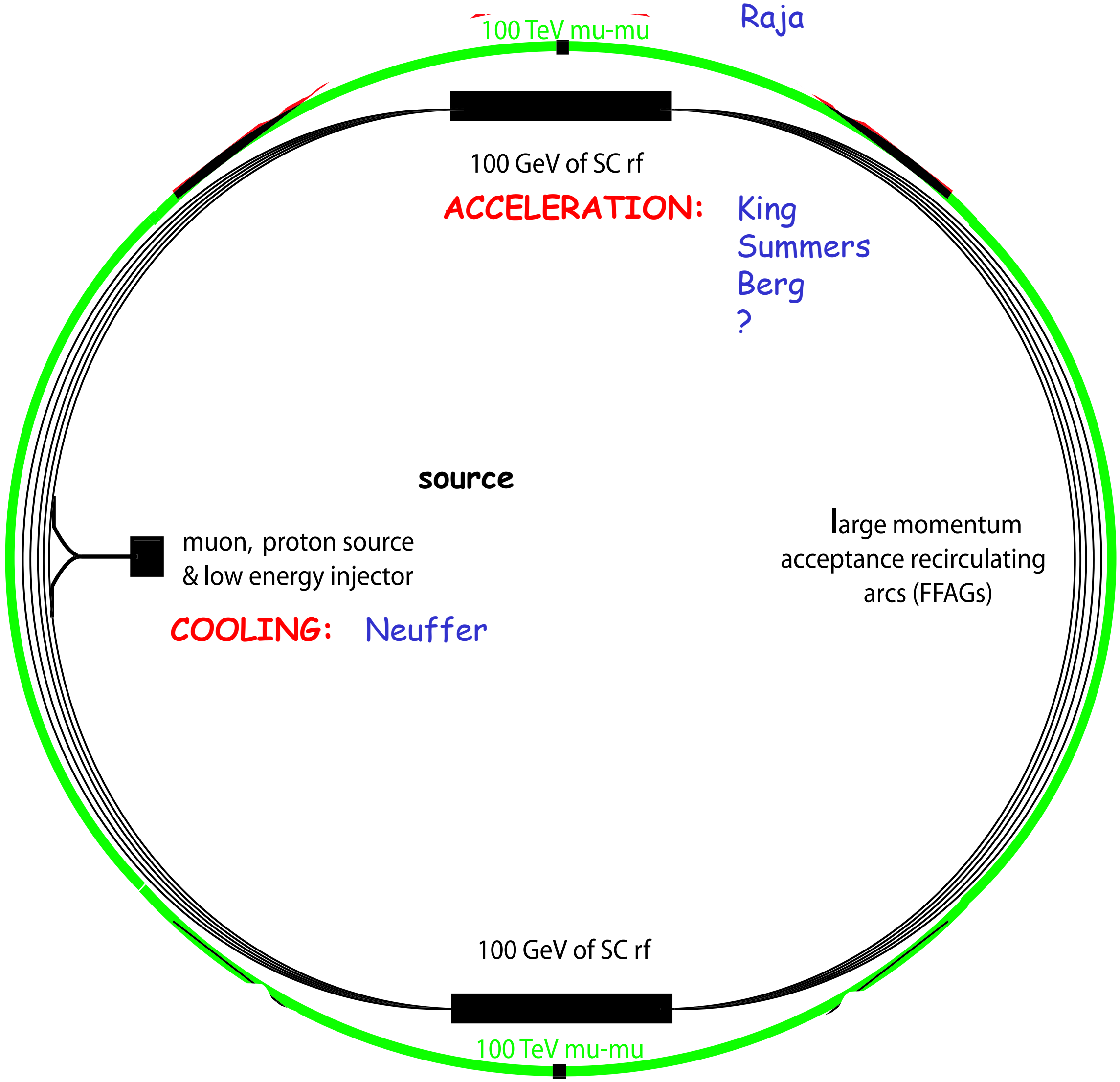


see Mokhov talk in this session

EXAMPLE SITE IN A "NEUTRAL" COUNTRY

... operated with Global Accelerator Network

TOPIC FOR THIS SESSION: PLAUSIBILITY OF (CIRCULAR) MUON COLLIDERS TO 100 TeV ENERGY SCALE



DETECTOR: Kahn, Raja

ACCELERATION: King, Summers, Berg, ?

COOLING: Neuffer

COLLIDER RING: Johnstone

MAGNETS: Gupta, McIntyre

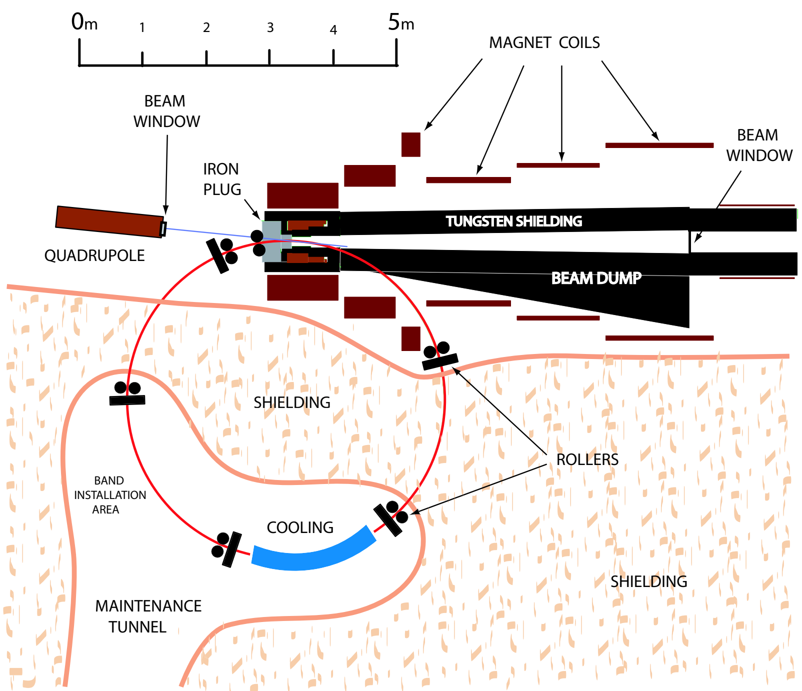
OTHER: Berger (HEP), Mokhov (ν rad.)

TARGETRY

• slated as the “other” main challenge (with cooling) for generic muon colliders in, e.g., 1999 APS Conference => lots of R&D including liquid mercury jet and radiative graphite targets

• now looks very manageable, e.g.:

(was T4 Session yesterday)



Ref. BJK, Mokhov, Simos & Weggel,

“A Rotating Metal Band Target for Pion Production at Muon Colliders”,

Proc. 6-Month Study on HEMC’s

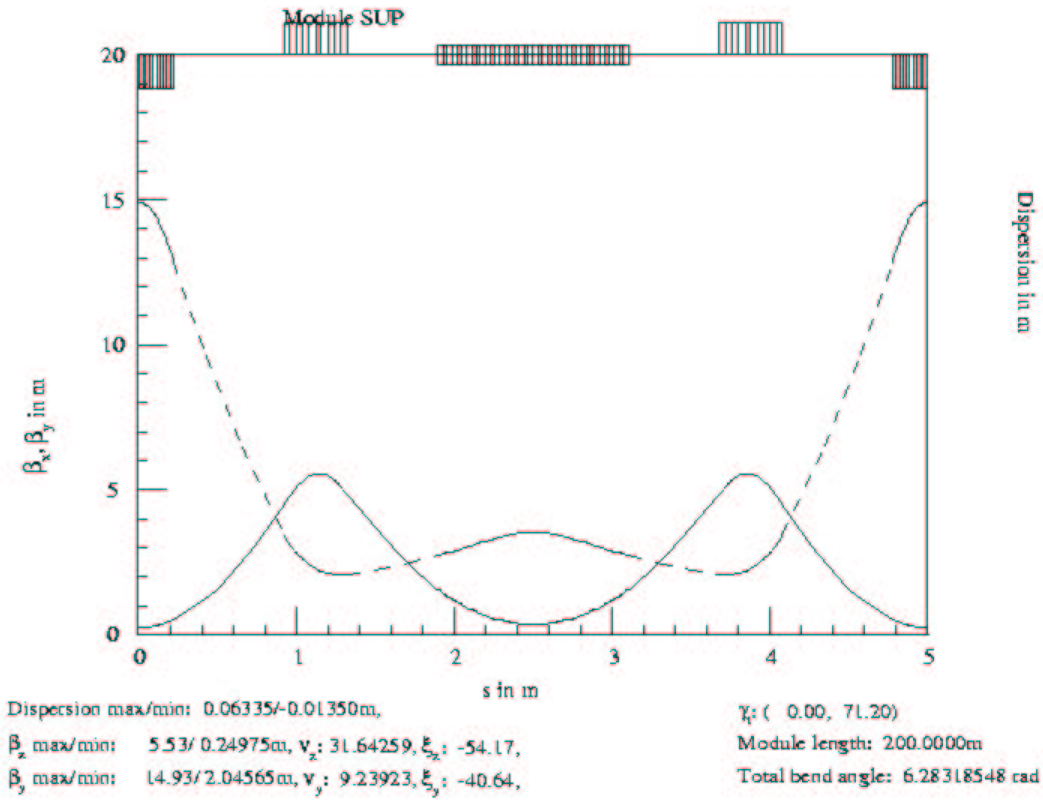
(available on CD here at Snowmass)

• in detailed MARS + ANSYS stress simulations, Ti-alloy target has von Mises stress only 10-14% of fatigue strength for a multi-MW pulsed proton beam that produces 4×10^{12} mu/sign/bunch (~max. for muon collider parameters)

• engineers think it can be designed, built & operated

ACCELERATION IN FFAGs

Acceleration will be the main cost driver for VLMCs. Cost reduction => acceleration in (e.g.) FFAG lattices. (Lattices of SC+fast-ramping magnets are also under consideration - Summers, Palmer.)



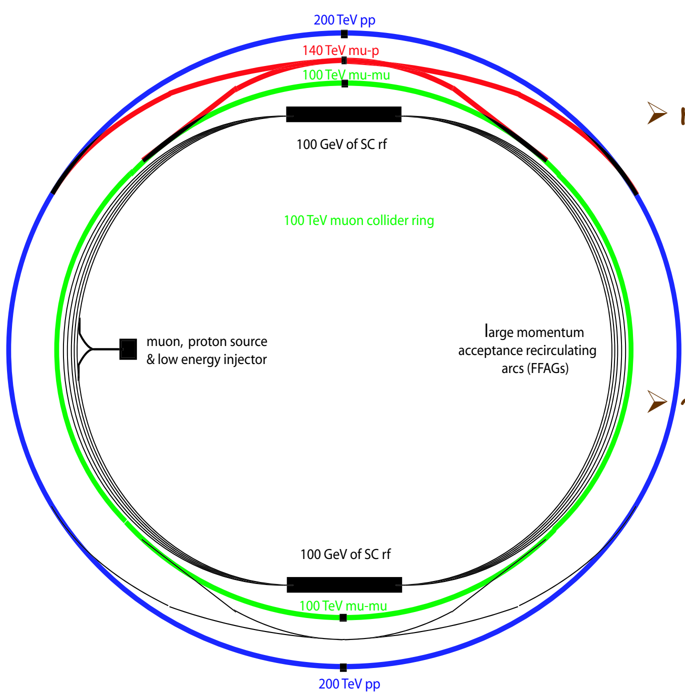
FFAGs invented by Symon in early '50s

resurrected for muon colliders by:

Mills
Johnstone
Garren
Trbojevic
Courant
Keil
Autin
Schonauer
Machida, Mori et al. (KEK ν fact.)

The figure shows a module of an FFAG lattice for 10->20 GeV by Trbojevic (+ Courant & Garren). Trbojevic expects such FFAG lattices to work well at very high energies (work in progress - we will know soon).

ACCELERATION STRATEGY



- ~200 GeV/turn of SC rf cavities, matched to beam for high efficiency
  - 50 TeV/200 GeV => 250 passes
  - Padamsee calculated 53% (10 TeV) or 33% (100 TeV) efficiencies for HEMC'99 parameters
- multiple recirculating arcs of FFAGs, each providing a factor of 2+ in energy
  - all arcs have same transit time => matched to rf
  - 1000 ~ 2^{10} => 10 FFAG arcs, or less
- ~ e^{-1} is non-decaying fraction loss for 100 GeV -> 50 TeV/beam

  => need 1.9e12 -> 0.7e12 muons (OK)